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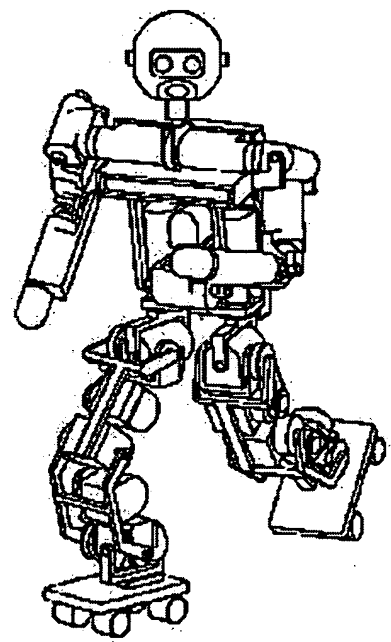
(54) LEG TYPE MOBILE ROBOT AND CONTROL METHOD FOR ITS MOTION

(57)Abstract:

PROBLEM TO BE SOLVED: To generate dynamic and high-speed moving operations of a leg type mobile robot more than in its normal walking motion by allowing the robot to put on roller skating shoes.

SOLUTION: This robot is composed of a lower body part consisting of two movable legs and a trunk and generates various motion patterns by controlling the whole body motions using the lower and upper body parts. A sliding unit having a specified sliding direction is removably attached to the bottom of each moving leg, and the moving speed is maintained by putting the sliding units approximately identical to the sliding direction while the moving speed can be braked by making different the sliding units from the sliding direction.



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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to a realistic robot's mechanism constituted by modeling a living body's mechanism and actuation, and relates to the mechanism of the leg formula migration mold robot which modeled the body mechanism of leg formula migration mold animals, such as Homo sapiens and an ape, especially.
[0002] Furthermore, this invention relates to mechanism and its control approach of the leg formula migration mold robot which can realize a flexible pattern of operation when each movable foot repeats implantation and bed-leaving actuation cooperatively and performs them, and it is related in detail to mechanism and its control approach of the leg formula migration mold robot which equips each movable foot with a skid unit like roller skate shoes, and performs dynamic and high-speed migration actuation especially.
[0003]
[Description of the Prior Art] It is said that a robot's origin of a word originates in ROBOTA (slave machine) of a slab word. Although it was in our country that a robot began to spread from the end of the 1960s, the many were the industrial robots (industrial robot) in works aiming at automation, full automation, etc. of production, such as a manipulator and a carrier robot.
[0004] Recently, the researches and developments about the leg formula mobile robot which imitated the body mechanism of the animal which performs 2-pair-of-shoes walks in erect posture, such as Homo sapiens and an ape, and actuation progress, and the expectation for utilization has also been growing. although the leg formula migration by 2-pair-of-shoes erection is compared with a crawler type, 4 pairs of shoes or a 6-pair-of-shoes type, etc., it is unstable and attitude control and walk control become difficult -- rise and fall of a stairway and an obstruction -- getting over -- etc. -- it excels in the point that flexible walk / transit actuation is realizable.
[0005] For example, to JP,3-184782,A, it is indicating about the Seki nodal character applied to the structure which corresponds below a fuselage among leg formula bipedal robots.
[0006] The thing of the leg formula mobile robot which emulated a human living body mechanism and actuation is especially called the robot (humanoid robot) of "a human form" or "a human mold." A humanoid robot can perform assisted living, i.e., exchange of the human activity in various scenes on the everyday life of living conditions and others etc.
[0007] The meaning which studies and develops the robot called a human form or a human mold can be grasped from the following two views.
[0008] One is a human science-view. That is, the robot of the structure similar to human being's membrum inferius and/or upper extremity can be made, the control approach can be devised, and the mechanism of natural actuation of human beings including a walk can be solved in engineering through the process of simulating walk actuation of human being. Such a research result could greatly return human engineering, rehabilitation engineering, or sports science to progress of other various areas of research treating human being's movement mechanism.

[0009] Another supports a life as human being's partner, namely, is development of the robot which supports the human activity in various scenes on the everyday life of living conditions and others. In various aspects of affairs of human being's living environment, learning from human being, this kind of robot needs to learn separately the adaptation approach to human being or the environment where individuality is different, and needs to grow up to be it further in respect of a function. At this time, the direction where the robot is having "a human form", i.e., the same form as human being, or the same structure is considered to function effectively, when performing smooth communication with human being and a robot.
[0010] In for example, the case so that the approach of passing through the room while avoiding the obstruction which must not be stepped on may be taught to a robot in practice Rather than it is having structure where the partner who teaches like a crawler type or a 4-pair-of-shoes type robot completely differs from himself It is easy to teach far. the direction of the 2-pair-of-shoes bipedal robot which is dressing the same -- a user (worker) -- Moreover, it is easy to learn also for a robot (for example, refer to the Takanishi work "control of a 2-pair-of-shoes bipedal robot" (Society of Automotive Engineers of Japan Kanto branch <quantity **> No.25, 1996APRIL)). First of all, it can be said that it is indispensable that the robot has the gestalt of a human mold when raising compatibility with human being's living conditions since most living conditions of human being are formed according to the gestalt and behavioral pattern which human being has.
[0011] As one of the applications of a humanoid robot, vicarious execution of various kinds of difficulty activities in an industrial activity, a production activity, etc. is mentioned. For example, it is vicarious execution of the maintenance in a nuclear power plant, a thermal power station plant, and a petrochemical plant, conveyance and assembly operation of the components in a plant, cleaning in a skyscraper, and the risk activity and difficulty activity like the rescue in a fire site and others etc. However, there is not necessarily no need of reproducing faithfully the body mechanism and actuation which it is the supremacy theme on a design / manufacture the robot which specialized in this kind of industrial use realizing a specific application or a specific function, and walk-in-erect-posture animals, such as Homo sapiens and an ape, originally have although it is premised on a 2-pair-of-shoes walk as a machinery. For example, in order to realize a specified use, while strengthening a hand's degree of freedom and moving function, restricting degrees of freedom, such as a head made comparatively low [relation], and the truncus section, the lumbar part (spine etc.), to an application, and omitting ** should approve to some extent. Consequently, although unnaturalness may remain as Homo sapiens by the exterior of a robot's activity or actuation also in a 2-pair-of-shoes walk and ******, this point cannot but reach a compromise.
[0012] Moreover, the application of "symbiosis" with a life adhesion mold, i.e., human being, is mentioned rather than assisted living, such as vicarious execution of a difficulty activity, as other applications of a humanoid robot. This kind of robot reproduces faithfully the mechanism of the whole body coordination mold which the animal which performs the walks in erect posture, Homo sapiens, an ape, etc., of 2 pairs of shoes originally has of operation, and sets it as the supremacy purpose to realize that automatically smooth actuation. Moreover, if the high erection animal of the intelligence of Homo sapiens, an ape, etc. is emulated at all, it is desirable for the power of expression of operation using the limbs to be rich. Furthermore, it is required it not only performs faithfully the pattern of operation inputted beforehand, but that it should realize the lively expression of operation in response to a partner's language and attitudes ("it strikes"). ["it praises" or "he scolding",] In this semantics, the entertainment robot which imitated Homo sapiens is suitable for just calling it a "humanoid robot."
[0013] The body is already equipped with the degree of freedom which goes up to hundreds of joints, i.e., hundreds, as everyone knows. Although it is desirable to give the almost same degree of freedom in order to give a leg formula mobile robot the infinite actuation near Homo sapiens, this is very difficult technically. Because, although it is necessary to arrange one actuator each at least to one degree of freedom, it is equal [mounting hundreds of actuators on a machinery called a robot] impossible also from a viewpoint of designs, such as weight and size, also from the point of a manufacturing cost. Moreover, if there are many degrees of freedom, only in the part, the computational complexity for a

robot's location and pattern control of operation, posture stability control, etc. will increase exponentially.
[0014] For this reason, it is common to constitute a humanoid robot from about dozens joint degrees of freedom far fewer than the body. Therefore, how it realizes can call more natural actuation one of the important technical problems in a design and control of a humanoid robot using few degrees of freedom.

[0015] For example, it is already clear from viewpoints, such as human engineering, that it is important in order that the device which has flexibility like a spine may carry out actuation various at the place of a life of human being and complicated. Although the application top with the industrial truncus joint degree of freedom which means a spine has low existence value, it is important for the humanoid robot of the life adhesion mold of entertainment or others. in addition -- and it is called for that adaptability can be actively adjusted according to a situation.
[0016] moreover, since a center-of-gravity location becomes high while the leg formula mobile robot which performs a 2-pair-of-shoes walk in erect posture is excellent in the point that flexible walk / transit actuation, such as etc., for example, rise and fall of a stairway and an obstruction -- getting over -- is realizable, only in the part, attitude control and stable walk control become difficult. Especially, in the case of the robot of a life adhesion mold, a posture and a stable walk must be controlled, expressing richly the natural actuation and the feeling in intelligence animals, such as Homo sapiens and an ape.
[0017] The attitude control about the robot of a type which performs leg formula migration by 2-pair-of-shoes walk, and the technique about a stable walk are already proposed plentifully. Stable "walk" said here can be defined as "Moving using a foot, without falling."
[0018] These moments act on gravity, inertial force, and a list from a walk system at a road surface with the acceleration produced in connection with gravity and locomotion at the time of a walk. According to so-called "d'Alembert's principle", they balance with the floor reaction force as reaction from a road surface to a walk system, and the floor-reaction-force moment. As a conclusion of dynamic inference, the point (Zero Moment Point), i.e., "ZMP", that a pitch and the roll-axes moment serve as zero exists in the vola grounding point and side top of the support polygon which a road surface forms, or its inside.
[0019] Many of proposals about a stable walk of a robot are used as a norm of stability distinction of a walk of this ZMP. The 2-pair-of-shoes walk pattern generation based on a ZMP norm can set up the point landing [vola] beforehand, and has the advantage of being easy to take the kinematic constraint of the tip of a foot according to a road surface configuration into consideration.
[0020] For example, to JP,5-305579,A, it is indicating about a leg formula mobile robot's walk control unit. A walk control unit given in this official report is controlled to make in agreement with desired value the point on the floor line where the moment by the floor reaction force when ZMP(ing) namely, (ZeroMoment Point) walking serves as zero.
[0021] Moreover, the leg formula mobile robot given in JP,5-305581,A constituted, as ZMP had ZMP in the location which has predetermined allowances at least from the edge of a support polyhedron (polygon) at the time of the interior of a support polyhedron (polygon) or landing, and bed leaving. Consequently, even if it receives disturbance etc., only predetermined distance has the allowances of ZMP, and improvement in the stability of a walk can be aimed at.
[0022] Moreover, to JP,5-305583,A, it is indicating about the point which controls a leg formula mobile robot's walk rate by the ZMP target position. That is, a leg formula mobile robot given in this official report detects the inclination of the upper part of the body, and is made to change the discharge rate of the walk pattern data set up according to the detection value while he drives a leg joint using the walk pattern data set up beforehand so that ZMP may be made in agreement with a target position. Consequently, when unexpected irregularity is stepped on and a robot inclines forward, for example, a posture can be recovered by discharge speeding up. Moreover, since ZMP can control to a target position, it is convenient even if it changes a discharge rate in a double stance phase.
[0023] Moreover, to JP,5-305585,A, it is indicating about the point which controls a leg formula mobile robot's landing location by the ZMP target position. That is, a leg formula mobile robot given in this official report performs a stable walk by detecting the gap with a ZMP target position and an

observation location, driving one side or the both sides of the leg so that it may be canceled, or driving the leg so that the moment may be detected and it may become zero to the circumference of a ZMP target position.

[0024] Moreover, to JP,5-305586,A, it is indicating about the point which controls a leg formula mobile robot's inclination posture by the ZMP target position. That is, a leg formula mobile robot given in this official report performs a stable walk by driving the leg so that it may become zero, when the moment of the circumference of a ZMP target position is detected and the moment has arisen.

[0025]

[Problem(s) to be Solved by the Invention] As mentioned above, about walk actuation of a leg formula migration mold robot, plentiful research and development which used ZMP for the norm whenever [stability distinction] have already been made.

[0026] However, although walk actuation is important as a leg formula mobile robot's basic actuation pattern, they are not all the patterns of operation. First of all, leg formula migration is the description excellent in flexible walk / transit actuation being possible, riding **** of rise and fall of a stairway or an obstruction is performed, and also the leg formula mobile robot should support jump actuation and the jumping-off actuation from a height.

[0027] Moreover, in the case of the humanoid robot for entertainment, performing the exercise of the whole body relevant to various kinds of events, such as a game and a sport, further is expected besides the fundamental pattern of operation on the everyday life of human beings, such as a walk and transit, and a jump.

[0028] For example, probably, a floor line top may be slid by making a leg formula mobile robot wear roller skate shoes. Because application in roller skating of a robot only demonstrates enjoyableness, it does not remain, but it also has the advantage that migration more dynamic than the usual walk actuation and quick can be realized without changing other devices. For example, probably, the robot which wore roller skate shoes is also applicable at the time of conveyance of a load etc.

[0029] In the conventional leg formula mobile robot, migration with problems, such as the degree-of-freedom structure, to passing speed it is comparatively late (with a life-size leg formula mobile robot, the maximum passing speed is 2.0 km/h extent), and dynamic and high-speed was difficult.

[0030] As a conventional example of the leg formula mobile robot which moves by performing motion control of skating, quadrapedalism robot "TITAN" (Proceedings ofthe 1999 IEEE International Conference - Robotics & Automation Detroit, Michigan-May 1999) is mentioned. However, TITAN is not what is a 4-pair-of-shoes robot and assumed the walk in erect posture by 2 pairs of shoes, and has not necessarily targeted to imitate the mechanism of a life object like Homo sapiens. Moreover, TITAN does not propose about the skating motion control about the robot of a configuration of that the upper extremity was included.

[0031] The purpose of this invention is to offer mechanism and its control approach of the great leg formula migration mold robot which can realize a flexible pattern of operation, when each movable foot repeats implantation and bed leaving actuation cooperatively and performs them.

[0032] The further purpose of this invention is by wearing roller skate shoes to offer mechanism and its control approach of the great leg formula migration mold robot which can realize migration more dynamic than the usual walk and high-speed.

[0033]

[Means for Solving the Problem and its Function] This invention is made in consideration of the above-mentioned technical problem. The 1st side face It consists of membrum inferius which consists of two or more movable feet, and the upper part of the body arranged above this membrum inferius. The skid unit with the predetermined skid direction which is the leg formula mobile robot which realizes various kinds of patterns of operation by movement of the membrum inferius, and was arranged in the abbreviation lowest edge of said movable foot, The control means which carries out motion control of the exercise of the whole body using said membrum inferius and upper part of the body is provided. Said control means He is the leg formula mobile robot characterized by braking the passing speed accompanying skid actuation by adjusting the include angle which the skid direction of said skid unit and said mobile robot's

travelling direction make.
[0034] The skid unit said here is a "roller skating unit" which equipped the rear face of the vola with two or more rotation rollers, and it has the skid direction specified by the hand of cut of a roller.
[0035] The skid unit is attached free [attachment and detachment] to the movable foot. Therefore, a leg formula mobile robot can perform the usual leg formula migration actuation patterns, such as a walk and transit, only by removing a skid unit.
[0036] Loads, such as frictional force, are hardly applied to the travelling direction which met in the skid direction by the skid unit. For this reason, the passing speed under skid is maintainable by arranging the skid unit of each movable foot with a travelling direction. On the other hand, frictional force is impressed in the travelling direction (for example, it intersects perpendicularly with the skid direction) which is not in agreement in the skid direction. For this reason, while setting up the skid direction of a skid unit in one movable foot so that a leg formula mobile robot's travelling direction may be intersected when the time of skid initiation and passing speed slow down, acceleration actuation is realizable by beginning to kick this movable foot back. Moreover, a braking operation can be derived by generating frictional force between road surfaces by making a skid unit cross in the skid direction, and implanting this movable foot during a skid period.
[0037] therefore -- according to the leg formula mobile robot concerning this invention -- the usual joint degree of freedom -- with -- **** -- skid actuation can be performed only using the pattern of operation which can be realized easily, consequently dynamic and high-speed migration actuation can be performed.
[0038] A control means can prevent a fall of the robot under skid by performing posture stability control by ZMP locus control during the period when the leg formula mobile robot is performing a series of skid actuation.
[0039] Moreover, the leg formula mobile robot may have further a posture detection means to detect the inclination and/or posture of said upper part of the body, a touch-down check means to detect implantation and bed leaving of said movable foot, and a passing speed detection means to detect the passing speed by skid actuation. Moreover, a control means can perform posture stability control according a leg formula mobile robot to ZMP locus control based on the result which these posture detection means, the touch-down check means, and the passing speed detection means detected or computed.
[0040] Moreover, the 2nd side face of this invention consists of membrum inferius which consists of two or more movable feet, and the upper part of the body arranged above this membrum inferius. It is the motion-control approach of the leg formula mobile robot which realizes various kinds of patterns of operation by movement of the membrum inferius. The step which maintains passing speed by [which have the predetermined skid direction in the abbreviation lowest edge of said movable foot] carrying out skid unit arrangement and making the abbreviation coincidence of said skid unit carry out in said skid direction, It is the motion-control approach of the leg formula mobile robot characterized by providing the step which brakes the passing speed accompanying skid actuation by adjusting the include angle at which said leg formula mobile robot's travelling direction makes the skid direction of said skid unit.
[0041] Said skid unit may be attached free [attachment and detachment] to said movable foot.
[0042] Moreover, this motion-control approach may be equipped with the step further controlled by arranging the skid direction of the skid unit of each movable foot with a travelling direction to maintain the passing speed under skid.
[0043] Moreover, this motion-control approach may be equipped with the step which realizes acceleration actuation by beginning to kick this movable foot back while it sets up the skid direction of the skid unit of at least one movable foot further so that said leg formula mobile robot's travelling direction may be intersected.
[0044] Moreover, this motion-control approach may be equipped with the step which derives a braking operation by implanting this movable foot while it sets up the skid direction of the skid unit of at least one movable foot further so that said leg formula mobile robot's travelling direction may be intersected.

[0045] Moreover, this motion-control approach may be further equipped with the step which performs posture stability control of said leg formula mobile robot by ZMP locus control.
[0046] Moreover, a posture detection means by which said leg formula mobile robot detects the inclination and/or posture of said upper part of the body, It has further a touch-down check means to detect implantation and bed leaving of said movable foot, and a passing speed detection means to detect the passing speed by skid actuation. This motion-control approach Furthermore, based on at least one output of said posture detection means, a touch-down check means, and a passing speed detection means, you may have the step which performs posture stability control of said leg formula mobile robot by ZMP locus control.
[0047] The purpose, the description, and advantage of further others of this invention will become [rather than] clear by detailed explanation based on the example and the drawing to attach of this invention mentioned later.
[0048]
[Embodiment of the Invention] Hereafter, the example of this invention is explained in detail, referring to a drawing.
[0049] Signs that the human form or humanoid robot 100 with which operation of this invention is presented was viewed from each of the front and back are shown in drawing 1 and drawing 2 .
[0050] The humanoid robot 100 concerning this example can be attached in both **** for the roller skating unit 200, enabling free attachment and detachment. Signs that **** of a humanoid robot 100 is equipped with the roller skating unit 200 are shown in drawing 3 and 4. The roller skating unit 200 is a device unit for one or more rollers being attached in the rear face of the vola free [rotation], and realizing skid actuation.
[0051] As shown in drawing 3 , the slider 201 of a reverse T character configuration is arranged at the tip (for example, lower limit of the ankle joint section) of the leg unit of a humanoid robot 100 for the cross section. On the other hand, the guide rail 202 which inserts a slider 201 is made by the guide-peg Hiragami side of the roller skating unit 200.
[0052] Near the insertion opening of a guide rail 202, the stopper 203 of the letter of a projection is arranged free [frequent appearance] from the top face of ****. As shown in drawing 3 , where a stopper 203 is buried, insertion opening of a guide rail 203 is opened wide completely, and becomes possible [removing the roller skating unit 200 with other **** units, and exchanging them]. On the other hand, as shown in drawing 4 , the roller skating unit 200 is fixable at the tip of a leg unit by making a stopper 203 project in the condition that the guide rail 202 has received the slider 201 completely, to the maximum extent.
[0053] In drawing 5 , it is illustrating about the detection device attached in the roller skating unit 200. In order to control skid actuation like a roller skate suitably, it is necessary to detect the touch-down check of whether **** has grounded to the floor line as an input value for control, and the passing speed under skid.
[0054] About the former touch-down check, it is detectable using micro switch 211A and dog 211B. That is, a self-weight of a robot 100 is impressed to **** according to touch-down, by what **** sinks (that is, poked by dog 211B), micro switch 211B can operate and grounding existence can.be detected.
[0055] Moreover, about passing speed, it is computable based on the output of the encoder (rotation detection meter) 213 attached to the end face of a roller. That is, the product of the periphery of the encoded rotational frequency and a roller shows movement magnitude, and passing speed is computed by doing the division of the movement magnitude by elapsed time.
[0056] Signs that the actuation whose humanoid robot 100 which attached the roller skating unit 200 in both guide pegs glides over a road surface was viewed from each of the front and back are shown in drawing 6 and drawing 7 .
[0057] Even if it sees drawing 6 and drawing 7 , as it understands, the pattern of an exercise of the whole body required for skating is in the operating range permitted also from on the leg formula mobile robot's 100 degree-of-freedom structure. the joint degree of freedom which in other words it had standardly by applying the roller skating unit 200 to each movable foot of a robot 100 -- with -- **** --

a robot 100 can perform a dynamic and high-speed skid, i.e., migration actuation, using the pattern of operation which can be realized easily. (However, about calculation processing of an exercise-of-the-whole-body pattern for a humanoid robot 100 to perform skid actuation, it explains in detail by the after-mentioned.)

[0058] Furthermore, the joint degree-of-freedom configuration which this humanoid robot 100 possesses is typically shown in drawing 8 . A humanoid robot 100 consists of the truncus sections which connect the upper part of the body including two arms and a head 1, the membrum inferius which consists of the two legs which realize migration actuation, and an upper extremity and the membrum inferius as illustration.

[0059] The neck joint which supports a head 1 has three degrees of freedom called the neck joint yawing axis 2, the neck joint pitching axis 3, and the neck joint roll axes 4.

[0060] Moreover, each arm consists of the shoulder-joint pitching axis 8, the shoulder-joint roll axes 9, the overarm yawing axis 10, the elbow-joint pitching axis 11, the forearm yawing axis 12, a wrist joint pitching axis 13, wrist joint roll axes 14, and a hand part 15. Hand parts 15 are the many joints and the multi-degree-of-freedom structure containing two or more fingers in fact. However, since there are little the contribution and effect to posture stability control or walk motion control of a robot 100, the actuation of a hand part 15 itself assumes on these specifications that it is a zero degree of freedom. Therefore, each arm on either side presupposes that it has seven degrees of freedom.

[0061] Moreover, the truncus section has three degrees of freedom called the truncus pitching axis 5, the truncus roll axes 6, and the truncus yawing axis 7.

[0062] moreover, the leg of each right and left which constitute the membrum inferius consists of the hip joint yawing axis 16, the hip joint pitching axis 17, the hip joint roll axes 18, the knee-joint pitching axis 19, an ankle joint pitching axis 20, joint roll axes 21, and a foot (vola) 22. The intersection of the hip joint pitching axis 17 and the hip joint roll axes 18 shall define the hip joint location of the robot 100 concerning this example. In fact, although the foot (vola) 22 of the body is the structure containing the vola of many joints and many degrees of freedom, the vola of the humanoid robot 100 concerning this example makes it a zero degree of freedom. Therefore, each leg on either side consists of six degrees of freedom.

[0063] If the above is summarized, as the humanoid robot 100 whole concerning this example, it will have 2= 3+7x2+3+6x32 degree of freedom in total. However, the humanoid robot 100 for entertainment is not necessarily limited to 32 degrees of freedom. It cannot be overemphasized that a degree of freedom, i.e., the number of joints, can be suitably fluctuated according to a constraint, requirement specification, etc. on a design / manufacture.

[0064] The degree of means is mounted using an actuator in fact each one which the humanoid robot 100 which was mentioned above has. As for the request of eliminating an excessive swelling by the exterior and making it approximate in the shape of [human] a natural bodily shape, performing attitude control to the unstable structure called a 2-pair-of-shoes walk to an actuator, it is desirable that it is small and lightweight. In this example, we decided to carry the small AC servo actuator of the type which was a gear direct attachment type, and one-chip-ized the servo control system and was built in the motor unit. In addition, it is indicated about this kind of AC servo actuator by the Japanese-Patent-Application-No. No. 33386 ['11 to] specification already transferred, for example to these people.

[0065] The control-system configuration of a humanoid robot 100 is typically shown in drawing 9 . As shown in this drawing, a humanoid robot 100 consists of each device units 30 and 40 expressing the human limbs, 50 R/L, 60 R/L, and a control unit 80 that performs adaptive control for realizing coordination actuation between each device unit (however, each of R and L is a suffix which shows each of the right and the left.). the following -- the same .

[0066] Actuation of the humanoid robot 100 whole is controlled by the control unit 80 in generalization. A control unit 80 consists of circumference circuits 82 including the interface (neither is illustrated) which performs the data of the main control section 81 which consists of main circuit components (not shown), such as a CPU (Central ProcessingUnit) chip and a memory chip, and each component of a power unit or a robot 100, and transfer of a command.

[0067] In this example, the power unit has composition (not shown to drawing 9) containing the dc-battery for driving a robot 100 independently. If it is an independence drive mold, the physical radius of action of a humanoid robot 100 cannot receive the limit by the power cable, but can walk it freely. Moreover, control of the actuation which it becomes unnecessary to take interference with a power cable into consideration, and includes a wide range field migration activity at the time of various kinds of movements including the upper extremity of a walk or others becomes easy.
[0068] Each joint degree of freedom in the robot 100 which showed drawing 8 is realized by the actuator corresponding to each. That is, the neck joint yawing-axis actuator A2 expressing each of the neck joint yawing axis 2, the neck joint pitching axis 3, and the neck joint roll axes 4, neck joint pitching-axis actuator A3, and neck joint roll-axes actuator A4 are arranged in the head unit 30, respectively.
[0069] Moreover, truncus pitching-axis actuator A5 expressing each of the truncus pitching axis 5, the truncus roll axes 6, and the truncus yawing axis 7, the truncus roll-axes actuator A6, and the truncus yawing-axis actuator A7 are arranged by the truncus section unit 40, respectively.
[0070] Moreover, although subdivided by overarm unit 51 R/L, elbow-joint unit 52 R/L, and forearm unit 53 R/L, arm unit 50 R/L The shoulder-joint pitching-axis actuator A8, shoulder-joint roll-axes actuator A9 expressing each of the shoulder-joint pitching axis 8, the shoulder-joint roll axes 9, the overarm yawing axis 10, the elbow-joint pitching axis 11, the elbow-joint roll axes 12, the wrist joint pitching axis 13, and the wrist joint roll axes 14, The overarm yawing-axis actuator A10, the elbow-joint pitching-axis actuator A11, the elbow-joint roll-axes actuator A12, the wrist joint pitching-axis actuator A13, and the wrist joint roll-axes actuator A14 are arranged, respectively.
[0071] Moreover, although subdivided by femoral region unit 61 R/L, knee unit 62 R/L, and leg part unit 63 R/L, leg unit 60 R/L The hip joint yawing-axis actuator A16 expressing each of the hip joint yawing axis 16, the hip joint pitching axis 17, the hip joint roll axes 18, the knee-joint pitching axis 19, the ankle joint pitching axis 20, and the ankle joint roll axes 21, the hip joint pitching-axis actuator A17, the hip joint roll-axes actuator A18, The knee-joint pitching-axis actuator A19, the ankle joint pitching-axis actuator A20, and the ankle joint roll-axes actuator A21 are arranged, respectively.
[0072] Each actuator A2 and A3-- are the small AC servo actuators (above-mentioned) of the type which was a gear direct attachment type, and one-chip-ized the servo control system and was more preferably carried in the motor unit.
[0073] The sub control sections 35, 45, 55, and 65 for actuator drive control are arranged, respectively for every device unit, such as the head unit 30, the truncus section unit 40, the arm unit 50, and each leg unit 60. furthermore, each leg 60 -- while equipping with the touch-down check sensors 91 and 92 which detect whether the vola of R and L was implanted, and the passing speed sensors 94 and 95 which detect passing speed, the attitude sensor 93 which measures a posture is equipped in the truncus section unit 40.
[0074] In this example, an acceleration sensor shall be used as an attitude sensor 93. Moreover, each of the touch-down check sensors 91 and 92 consists of combination of micro switch 211A and dog 211B, as explained referring to drawing 5 . Moreover, each of the passing speed sensors 94 and 95 is constituted by the encoder 213 (rotation detection meter) attached to the roller end side of the skating unit 200. It can distinguish any of a skid foot or **** implantation and bed leaving period, as a result leg unit of the vola 22 are with the output of the touch-down check sensors 91 and 92. Moreover, a robot's 100 planing speed is computable by adopting the encoder output of a leg unit used as a skid foot. Moreover, the inclination and posture of a truncus part are detectable with the output of an attitude sensor.
[0075] The main control section 80 can answer the output of each sensors 91-93, and can amend control objectives dynamically. Accommodative control can be performed to each of the sub control sections 35, 45, 55, and 65, and, more specifically, actuation with which the upper extremity of a humanoid robot 100, the truncus, and the membrum inferius cooperated can be realized. the main control section 81 -- a user command etc. -- following -- a foot -- while setting up movement, a ZMP (Zero Moment Point) orbit, truncus movement, upper extremity movement, lumbar part height, etc., the command which directs actuation according to these contents of a setting is transmitted to each sub control sections 35,

45, 55, and 65.
[0076] And in each sub control section 35 and 45 --, the receiving command from the main control section 81 is interpreted, and a drive control signal is outputted to each joint actuator A2 and A3--. "ZMP" said here is a point on the floor line where the moment by the floor reaction force during a walk serves as zero, and a "ZMP orbit" means the locus to which ZMP moves during a robot's 100 walk actuation period etc.
[0077] Subsequently, what "is made to wear roller skate shoes to a robot 100" explains the control procedure for realizing migration more nearly high-speed than a walk.
[0078] In this example, the humanoid robot 100 possessing the multi-joint degree-of-freedom configuration physically shown in drawing 8 is further transposed to a multi-material point approximation model, and data processing of calculation of an exercise-of-the-whole-body pattern is performed. Although the actual humanoid robot 100 is the aggregate of infinity, i.e., the continuous material point, they are the purposes with main reducing the computational complexity by transposing to the approximation model which consists of the discrete material point by the finite number.
[0079] The linearity of a humanoid robot 100 introduced into drawing 10 for count of the exercise-of-the-whole-body pattern concerning this example and the multi-material point approximation model of noninterfering are illustrated.
[0080] In drawing 10 , O-XYZ system of coordinates express roll [in an absolute coordinate system], pitch, and yaw each shaft, and O'-X'Y'Z' system of coordinates express roll [in the movement system of coordinates which move with a robot 100], pitch, and yaw each shaft. i is a suffix showing the material point given to the i-th, mi shall express the mass of the i-th material point, and r'i shall express the position vector (however, movement system of coordinates) of the i-th material point with the multi-material point model shown in this drawing. Moreover, in the lumbar part kinematic control mentioned later, especially mass of the important lumbar part material point is set to mh, and the position vector sets it as r'h (r'hx, r'hy, r'hz), and the position vector of ZMP is made into r'zmp.
[0081] non-** shown in drawing 10 -- in a dense multi-material point approximation model, a moment equation should be described in the form of a linear equation, and please understand enough the point that this moment equation does not interfere about a pitching axis and roll axes.
[0082] Such a multi-material point approximation model is generable in general with the following procedure.
[0083] (1) Search for the mass distribution of the robot 100 whole.
(2) Set up the material point. Even if the setting approach of the material point is a designer's manual input, neither of automatic generation according to a predetermined regulation is available for it.
(3) Ask each field i of every for a center of gravity, and give the center-of-gravity location and mass mi to the corresponding material point.
(4) Display as a solid sphere which has each material point mi in the radius which is proportional to the mass centering on the material point location ri.
(5) Connect the material point, i.e., the solid spheres, which have connection-related actually.
[0084] So to speak, a multi-material point approximation model expresses a robot 100 with the gestalt of a wireframe model. In this example, this multi-material point approximation model sets up each of both shoulders, both elbows, both wrists, the truncus, the lumbar part, and both ankles as the material point so that it may understand, even if it sees drawing 10 .
[0085] In addition, each angle of rotation (thetahx, thetahy, thetahz) in the lumbar part information on the multi-material point model shown in drawing 10 specifies rotation of the posture of the lumbar part in a humanoid robot 100, i.e., a roll, a pitch, and a yawing axis (in drawing 11 , since the enlarged drawing of the lumbar part circumference in a robot's 100 multi-material point approximation model is shown, please check).
[0086] Subsequently, the calculation procedure of an exercise-of-the-whole-body pattern for the humanoid robot 100 concerning this example to perform skid actuation is explained.
[0087] A robot usually realizes predetermined actuation by carrying out drive control of each joint, i.e., the actuator, according to the movement pattern generated beforehand, before operating. the case of the

robot 100 concerning this example -- the foot of arbitration -- based on a movement pattern, a ZMP orbit, a truncus movement pattern, an upper extremity movement pattern, etc., the lumbar part movement pattern which enables stable skating movement is generated. In a leg formula mobile robot, the ZMP (Zero Moment Point) orbit said here means a point which the moment does not generate during the period which performs the exercise-of-the-whole-body pattern of a walk, roller skating, and others, when the vola (or sole) is fixed to a floor line by one certain point (above-mentioned).

[0088] the case of the leg formula mobile robot (refer to drawing 8) with which one movable foot has six degrees of freedom like this example -- each -- a foot -- the posture of a biped becomes settled uniquely with the location of 22 R/L, the horizontal position of the lumbar part, and height. Therefore, generating the lumbar part movement pattern for skating actuation is exactly determining the posture of a foot, i.e., the "gait" of the membrum inferius. (A "gait" (gait) is terminology which means the thing of the pattern (for example, a guide peg floating pattern about the sequence of the direction, its timing, etc.) of the membrum inferius especially at the time of a walk of operation among a multi-foot robot's patterns of operation.) A multi-foot robot's gait is expressed using the phase contrast and the duty ratio of a foot (based on the collection of robot technical terms of Robotics Society of Japan).

[0089] In the form of the flow chart shows the control procedure of lumbar part movement for realizing skating actuation stabilized by the robot 100 concerning this example to drawing 12 . However, below, suppose that a parameter as described each joint location of a robot 100 and actuation using linearity and a noninterfering multi-material point approximation model as shown in drawing 10 and shown in the following [-one numbers] on the occasion of count is used. Moreover, please understand the notation with a dash (') to be what describes the parameter of movement system of coordinates etc.

[0090]

[Equation 1]

m_h :腰部質点の質量

$\vec{r}'_h(r'_{hx}, r'_{hy}, r'_{hz})$:腰部質点の位置ベクトル

m_i :i番目の質点の質量

$\vec{r}'_i$:i番目の質点の位置ベクトル

$\vec{r}'_{zmp}$:ZMPの位置ベクトル

$\vec{g}(g_x, g_y, g_z)$:重力加速度ベクトル

$O'-X'Y'Z'$:運動座標系（ロボットとともに動く）

$O-XYZ$:絶対座標系

$H = r'_{hz} + r_{qz}$

[0091] Moreover, it is premised on a robot's 100 lumbar part height being regularity (r'hz+rqz=const), and the knee region material point being zero.

[0092] The procedure shown in drawing 12 answers the input of the user command of the purport which directs actuation of a walk of a robot 100, a gesture, a gesture, etc., etc., and is started. By this example, the actuation of a robot 100 which a user command directs means skating actuation. However, directions of a user may include the gesture, the gesture, etc. using other actuation, for example, the upper extremity at the time of upright posture, the gesture and the gesture in which the truncus was used, and the upper extremity [usually] at the time of a 2-pair-of-shoes walk by 2 pairs of shoes, the time of a walk, and the truncus.

[0093] this user command is interpreted in the main control section 81 -- having -- a foot (specifically vola) -- movement and a foot -- the pattern for actually opting for a drive and actuation of each part, such as a ZMP orbit, truncus movement, upper extremity movement, and a posture, height of the lumbar part that are drawn from movement, is set up (step S11). more -- concrete -- first -- a foot -- a movement pattern -- subsequently a ZMP orbit, a truncus movement pattern, and an upper extremity movement

pattern are set up. Moreover, about movement of the lumbar part, only the direction of Z' is set up and suppose that it is strange about each direction of X' and Y'.
[0094] Next, each moment (Mx, My) of the circumference of a foot, the truncus and the pitching axis on the setup ZMP generated by upper extremity movement, and roll axes is computed using linearity and a noninterfering multi-material point approximation model (step S12).
[0095] Subsequently, the moment on the setup ZMP generated by movement within a lumbar part horizontal plane (r'hx, r'hy) is computed using linearity and a noninterfering multi-material point approximation model (step S13).
[0096] Subsequently, the balance type about the moment on Setup ZMP is derived on movement system-of-coordinates O'-X'Y'Z' which moves with a robot (step S14). The term (rhx, rhy) concerning the class leveling movement of the lumbar part material point in a foot, the truncus, and the moment (Mx, My) generated by upper extremity movement is more specifically summarized to the right-hand side as a term of a strange variable as a term of a known variable at left part, and linearity and a noninterfering ZMP equation (1) as shown in a bottom equation are derived.
[0097]
[Equation 2]

$$\begin{aligned} &+m_h H(\ddot{r}_{hx}+\ddot{r}_{qx}+g_x)-m_h g_z(r'_{hx}-r'_{zmp_x})=-M_y(t) \\ &-m_h H(\ddot{r}_{hy}+\ddot{r}_{qy}+g_y)+m_h g_z(r'_{hy}-r'_{zmp_y})=-M_x(t) \end{aligned} \qquad \cdots (1)$$

[0098] However, the following shall be materialized.
[0099]
[Equation 3]

$$\ddot{r}_{hz}=0$$

$$r'_{hz}+r_{qz}=\mathrm{const} \quad (\text{時間に関し一定})$$

[0100] Subsequently, the orbit within a lumbar part horizontal plane is computed by solving the above-mentioned ZMP equation (1) (step S15). For example, the numerical solution of the level absolute location (rhx, rhy) of the lumbar part as a strange variable can be calculated by solving a ZMP equation (1) using numerical solution methods (common knowledge), such as Euler's method and a Runge-Kutta method, (step S16). The numerical solution calculated here is an approximate solution of the lumbar part movement pattern in which a stable walk is possible, and is the lumbar part horizontal absolute location where ZMP more specifically goes into a target position. A ZMP target position is usually set as the implanted vola.
[0101] On the computed approximate solution, when the truncus and upper extremity movement set up beforehand cannot be realized, resetting and correction of the truncus and an upper extremity movement pattern are made (step S17). Under the present circumstances, the orbit of a knee region may be computed.
[0102] Subsequently, the moment (eMx, eMy) on the setup ZMP in a strict model (namely, the rigid body or the precise model of the robot 100 which consists of very many material points) is computed by substituting the exercise-of-the-whole-body pattern obtained as mentioned above (step S18). Although premised on the above-mentioned [-three number] being materialized in the un-strict model, this premise is not required if strict (that is, it does not need to be fixed to change of time amount).
[0103] The moment (eMx, eMy) in a strict model is a moment error which lumbar part movement generates. At continuing step S19, this moment (eMx, eMy) judges whether it is under the allowed value (epsilonMx, epsilonMy) of the approximation moment in an un-strict model. Since the exercise-of-the-whole-body pattern which can realize the strict solution of a lumbar part stability movement pattern and stable skating actuation was obtained when it was under the allowed value epsilon (step S20), this whole routine is ended.

[0104] on the other hand, when the moment (eMx, eMy) in a strict model is more than the allowed value (epsilonMx, epsilonMy) of the moment in an approximation model Until it corrects the known generating moment (Mx, My) in an approximation model using the moment (eMx, eMy) in a strict model (step S21), it derives a ZMP equation again and it converges under on the allowed value epsilon Calculation and correction of the approximate solution of a lumbar part movement pattern are repeated and made.
[0105] in order to perform roller skating actuation which uses a movable foot by turns and glides over it according to the procedure shown in drawing 12 -- a foot -- lumbar part movement which stabilizes the posture other than movement based on a setup of truncus movement or upper extremity movement is realizable. With truncus movement and upper extremity movement, it is equivalent to the expression actuation using the upper half of the body of robots, such as a gesture and a gesture. moreover, the case of the leg formula mobile robot 100 (refer to drawing 8) with which each movable foot consists of six degrees of freedom -- each -- a foot -- since the posture of a foot, i.e., the "gait" of the membrum inferius, becomes settled uniquely in the location of 22 R/L, the horizontal position of the lumbar part, and height, generating a lumbar part movement pattern means determining the "gait" of the membrum inferius.
[0106] Moreover, in the form of the flow chart shows other examples about the control procedure of lumbar part movement for performing skating actuation stabilized in the robot 100 concerning this example to drawing 13 . However, this procedure shall describe each joint location of a robot 100, and actuation like **** using linearity and a noninterfering multi-material point approximation model.
[0107] This procedure answers the input of the user command of the purport which directs actuation of a walk of a robot 100, a gesture, a gesture, etc., etc., and is started. By this example, the actuation of a robot 100 which a user command directs means skating actuation. However, directions of a user may include the gesture, the gesture, etc. using other actuation, for example, the upper extremity at the time of upright posture, the gesture and the gesture in which the truncus was used, and the upper extremity [usually] at the time of a 2-pair-of-shoes walk by 2 pairs of shoes, the time of a walk, and the truncus.
[0108] this user command is interpreted in the main control section 81 -- having -- a foot (specifically vola) -- movement and a foot -- the pattern for actually opting for a drive and actuation of each part, such as a ZMP orbit, truncus movement, upper extremity movement, and a posture, height of the lumbar part that are drawn from movement, is set up (step S31). more -- concrete -- first -- a foot -- a movement pattern -- subsequently a ZMP orbit, a truncus movement pattern, and an upper extremity movement pattern are set up. Moreover, about movement of the lumbar part, only the direction of Z' is set up and suppose that it is strange about each direction of X' and Y'.
[0109] Next, each moment (Mx, My) of the circumference of a foot, the truncus and the pitching axis on the setup ZMP generated by upper extremity movement, and roll axes is computed using linearity and a noninterfering multi-material point approximation model (step S32).
[0110] Subsequently, the fourier expansion into series of the movement within a lumbar part horizontal plane (r'hx, r'hy) is carried out (step S33). In this industry, by carrying out the fourier expansion into series, a time-axis component can be transposed to a frequency component, and can already be calculated as everyone knows. That is, a motion of the lumbar part can be regarded as a periodic motion in this case. Moreover, since FFT (restricted Fourier transform) is applicable, calculation speed can be raised sharply.
[0111] Subsequently, the fourier expansion into series is carried out also about each moment (Mx, My) of the circumference of the pitching axis on Setup ZMP, and roll axes (step S34).
[0112] Subsequently, the Fourier coefficients of the orbit within a lumbar part horizontal plane are computed, and the approximate solution of (step S35) and lumbar part movement can be found by carrying out reverse Fourier-series expansion further (step S36). The approximate solution calculated here is the lumbar part horizontal absolute location where it is the approximate solution (rhx, rhy) of the horizontal absolute location of the lumbar part which specifies the lumbar part movement pattern in which a stable walk is possible, and ZMP more specifically goes into a target position. A ZMP target position is usually set as the implanted vola.

[0113] On the computed approximate solution, when the truncus and upper extremity movement set up beforehand cannot be realized, resetting and correction of the truncus and an upper extremity movement pattern are made (step S37). Under the present circumstances, the orbit of a knee region may be computed.
[0114] Subsequently, the moment (eMx, eMy) on the setup ZMP in a strict model (namely, the rigid body or the precise model of the robot 100 which consists of very many material points) is computed by substituting the exercise-of-the-whole-body pattern obtained as mentioned above (step S38). Although premised on the above-mentioned [-three number] being materialized in the un-strict model, this premise is not required if strict (that is, it does not need to be fixed to change of time amount).
[0115] The moment (eMx, eMy) in a strict model is a moment error which lumbar part movement generates. At continuing step S39, this moment (eMx, eMy) judges whether it is under the allowed value (epsilonMx, epsilonMy) of the moment in an approximation model. Since the exercise-of-the-whole-body pattern which can realize the strict solution of lumbar part stability movement PATAN and stable skating actuation was obtained when it was under the allowed value epsilon (step S40), this whole routine is ended.
[0116] On the other hand, when the moment (eMx, eMy) in a strict model is more than the allowed value (epsilonMx, epsilonMy) of the moment in an approximation model, calculation and correction of the approximate solution of a lumbar part movement pattern are repeated and made until it corrects the known generating moment (Mx, My) in an un-strict model using the moment (eMx, eMy) in a strict model (step S41), it carries out the fourier expansion into series again and it converges under on the allowed value epsilon.
[0117] If it is this contractor, he will be able to understand that lumbar part movement in which the skating actuation stabilized based on the setup of truncus movement or upper extremity movement with the procedure shown in drawing 13 as well as the procedure shown by drawing 12 is possible is realizable. Especially, it does not depend on the numerical solution method of a ZMP equation, but while asking a high speed for periodic motion by using the fourier expansion into series, the moment count itself is accelerable by applying FFT (fast Fourier transform).
[0118] With truncus movement and upper extremity movement, it is equivalent to the expression actuation using the upper half of the body of robots, such as a gesture and a gesture. moreover, each movable foot -- the case of the leg formula mobile robot 100 (refer to drawing 8) of the joint degree of freedom of six pieces -- each -- a foot -- since the posture of a foot becomes settled uniquely in the location of 22 R/L, and the height of the lumbar part, generating a lumbar part movement pattern means determining the posture of a foot, i.e., the "gait" of the membrum inferius, (above-mentioned).
[0119] In drawing 14 - drawing 16 , the leg formula mobile robot 100 which equipped each movable foot with the roller skating unit 200 is illustrating the motion of each vola when performing movement which circles to rectilinear propagation or a longitudinal direction by skating actuation.
[0120] As shown in drawing 14 , the hip joint yawing-axis actuator of a right trail is made to drive first, and a right leg bottom is made into the sense which is not in agreement with a robot's 100 travelling direction, i.e., a pitching axis. In the example of illustration, to the x axis, i.e., roll axes, the right leg bottom is moved so that it may become abbreviation parallel. However, the crus-sinistrum-diaphragmatis section instead of the right trail section may be made to drive (please interpret it as **** of a foot on either side being exchanged similarly hereafter).
[0121] Furthermore, the initial velocity V0 of migration is impressed to the left leg section by performing actuation which is made to ground a right leg bottom and is kicked back. At this time, either rectilinear propagation, clockwise rotation and anticlockwise rotation can be chosen by setting the revolution include angle theta as a desired value.
[0122] By performing a series of above-mentioned ZMP locus control (referring to drawing 12 or drawing 13) which makes ZMP a stability judging norm working, the posture of the robot 100 at the time of skating initiation can be stabilized, and a fall can be prevented.
[0123] If a skid is started, it is accelerated in the direction of rectilinear propagation, clockwise rotation, or one of anticlockwise rotation and passing speed Vt is stabilized, as shown in drawing 15 , the vola on

either side will be arranged with a x axis, i.e., roll shaft orientations. Consequently, a robot 100 glides, decreasing passing speed maintaining the migration direction. Also during skid actuation, by performing ZMP locus control (referring to drawing 12 or drawing 13), a robot's 100 posture can be stabilized and a fall can be prevented.
[0124] If passing speed Vt declines to predetermined passing speed, as shown in drawing 16 , the hip joint yawing-axis actuator of crus sinistrum diaphragmatis will be made to drive, and a left leg bottom will be made into the sense which is not in agreement with a robot's 100 travelling direction, i.e., a pitching axis. In the example of illustration, to the x axis, i.e., roll axes, the left leg bottom is moved so that it may become abbreviation parallel.
[0125] Furthermore, the initial velocity V0 of migration is impressed to the left leg section by performing actuation which is made to ground a left leg bottom and is kicked back. At this time, either rectilinear propagation, clockwise rotation and anticlockwise rotation can be chosen by setting the revolution include angle theta as a desired value.
[0126] By performing a series of above-mentioned ZMP locus control (referring to drawing 12 or drawing 13) which makes ZMP a stability judging norm working, the posture of the robot 100 at the time of skating initiation can be stabilized, and a fall can be prevented.
[0127] A robot 100 can continue the stable skid actuation by repeating successively a pattern of operation called acceleration as shown in drawing 14 - drawing 16 , attenuation of a rate, and acceleration. Moreover, by setting up the revolution include angle theta in the case of acceleration, rectilinear propagation, clockwise rotation, and anticlockwise rotation can be performed suitably, and the locus of arbitration can also be drawn during a skid.
[0128] Moreover, to drawing 17 - drawing 19 , the leg formula mobile robot 100 which equipped each movable foot with the roller skating unit 200 is illustrating the motion of each vola when performing movement which slows down and/or stops during skating actuation.
[0129] Slow down the robot 100 under skid by skating, or to stop From the condition (refer to drawing 15) that the right leg bottom and the left leg bottom are parallel, and are moving forward, as shown in drawing 17 A robot's 100 passing speed Vt can be braked by making the right leg section or the left leg section ****, making a RWY side ground the foot which ****(ed), and adjusting the frictional force generated in that case.
[0130] By performing ZMP locus control (referring to drawing 12 or drawing 13) during such a series of braking actuation, a robot's 100 posture can be stabilized and a fall can be prevented.
[0131] or it is shown in drawing 18 from the condition (refer to drawing 15) that the right leg bottom and the left leg bottom are parallel, and are moving forward -- as -- the both sides of a right leg bottom and a left leg bottom -- the front end -- the inside -- and the seal of approval of the frictional force is carried out to a travelling direction, and passing speed Vt is made to decrease by making it outside suitable [the back end] At this time, braking can be adjusted by adjusting inclination theta of each vola to a travelling direction.
[0132] By performing ZMP locus control (referring to drawing 12 or drawing 13) during such a series of braking actuation, a robot's 100 posture can be stabilized and a fall can be prevented.
[0133] Or a robot's 100 passing speed Vt is attenuated and you may make it make it stop by equipping the rotation roller section with a brake function, and controlling this brake (refer to drawing 19). By performing ZMP locus control (referring to drawing 12 or drawing 13) also in this case, the posture of the robot 100 at the time of braking can be stabilized, and a fall can be prevented.
[0134] It has explained in detail about this invention, referring to a specific example more than [addenda]. However, it is obvious that this contractor can accomplish correction and substitution of this example in the range which does not deviate from the summary of this invention.
[0135] In this specification, although three degrees of freedom called a robot's truncus pitching axis 5, truncus roll axes 6, and truncus yawing axis 7 were treated as a posture (thetahx, thetahy, thetahz) of a robot's lumbar part, please interpret the location of the lumbar part flexibly by contrast with a humanoid robot 100 and the body mechanism of 2-pair-of-shoes walk-in-erect-posture animals, such as actual Homo sapiens and an ape.

[0136] In short, with the gestalt of instantiation, this invention has been indicated and it should not be interpreted restrictively. In order to judge the summary of this invention, the column of the claim indicated at the beginning should be taken into consideration.
[0137] The joint model building of a humanoid robot is illustrated to drawing 20 for reference. In the example shown in this drawing, the part which consists of an overarm, an elbow joint 6, a forearm, a wrist 7, and a hand part 8 is called a "upper extremity" from the shoulder joint 5. Moreover, it is equivalent to the fuselage of the "truncus section", a call, and Homo sapiens in the range from the shoulder joint 5 to a hip joint 11. Moreover, the range from the hip joint 11 to the truncus joint 10 is called the "lumbar part" especially among the truncus sections. The truncus joint 10 has the operation expressing the degree of freedom which the human backbone has. Moreover, the part which consists of the femoral region 12, the knee joint 14, the leg section 13, the ankle 15, and foot 16 below a hip joint 11 is called the "membrum inferius." Generally, it is [0138] which calls [hip joint] a lower part a "lower object" for the upper part from the "upper part of the body", a call, and it. Moreover, to drawing 21 , other joint model buildings of a humanoid robot are illustrated. The example shown in this drawing is different from the example shown in drawing 20 with the point of not having the truncus joint 10. Please refer to drawing about the name of each part. A motion of the upper part of the body of a humanoid robot loses power of expression as a result to which the truncus joint equivalent to the backbone is abbreviated. However, in the case of the humanoid robot of the industrial purpose, vicarious execution of a risk activity or a difficulty activity etc. may not require a motion of the upper part of the body. In addition, the reference number used by drawing 20 and drawing 21 should understand a conflicting point to be the other drawing.
[0139]
[Effect of the Invention] As a full account was given above, when each movable foot repeats implantation and bed leaving actuation cooperatively and performs them, according to this invention, mechanism and its control approach of the great leg formula migration mold robot which can realize a flexible pattern of operation can be offered.
[0140] Moreover, according to this invention, mechanism and its control approach of the great leg formula migration mold robot which can realize migration more dynamic than the usual walk and high-speed can be offered by wearing roller skate shoes.
[0141] equipping the abbreviation lowest edge of each movable foot with a skid unit according to the leg formula mobile robot concerning this invention -- the usual joint degree of freedom -- with -- **** -- skid actuation can be performed only using the pattern of operation which can be realized easily, consequently dynamic and high-speed migration actuation can be performed. The skid unit is attached free [attachment and detachment] to the movable foot. Therefore, a leg formula mobile robot can perform the usual leg formula migration actuation patterns, such as a walk and transit, only by removing a skid unit.
[0142] Loads, such as frictional force, are hardly applied to the travelling direction which met in the skid direction by the skid unit. For this reason, the passing speed under skid is maintainable by arranging the skid unit of each movable foot with a travelling direction. On the other hand, frictional force is impressed in the travelling direction (for example, it intersects perpendicularly with the skid direction) which is not in agreement in the skid direction. For this reason, while setting up the skid direction of a skid unit in one movable foot so that a leg formula mobile robot's travelling direction may be intersected when the time of skid initiation and passing speed slow down, acceleration actuation is realizable by beginning to kick this movable foot back. moreover, by looking the skid direction of a skid unit like [a leg formula mobile robot's travelling direction], making it intersect it, and implanting this movable foot during a skid period, frictional force is generated between road surfaces and a braking operation can be derived.
[0143] Moreover, a control means can prevent a fall of the robot under skid by performing posture stability control by ZMP locus control during the period when the leg formula mobile robot is performing a series of skid actuation.

[Translation done.]

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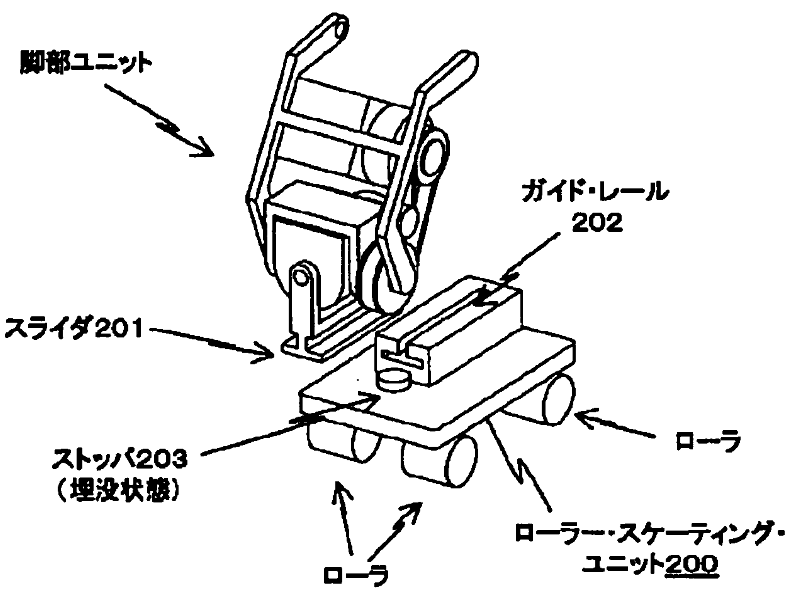
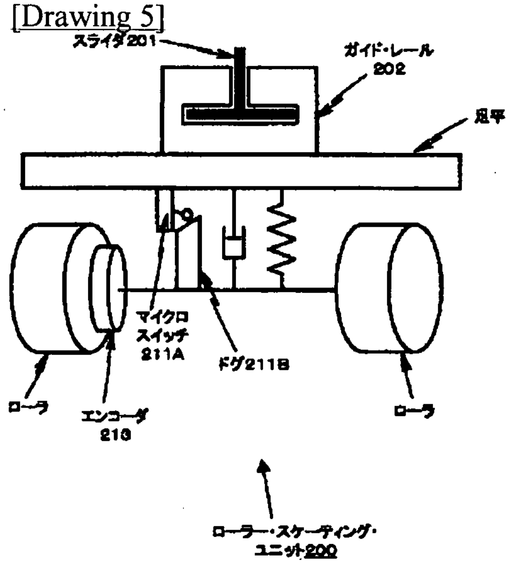
DRAWINGS

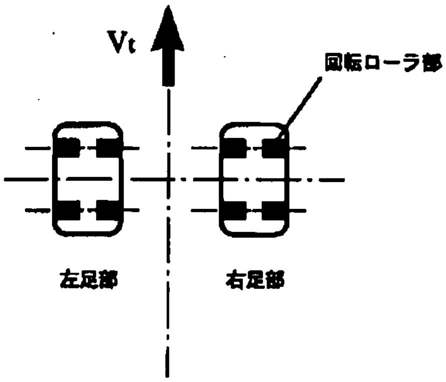
[Drawing 3]



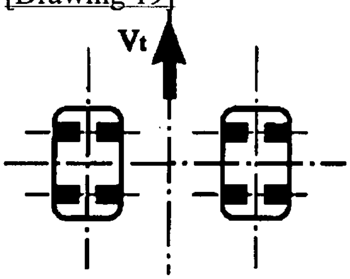
[Drawing 5]



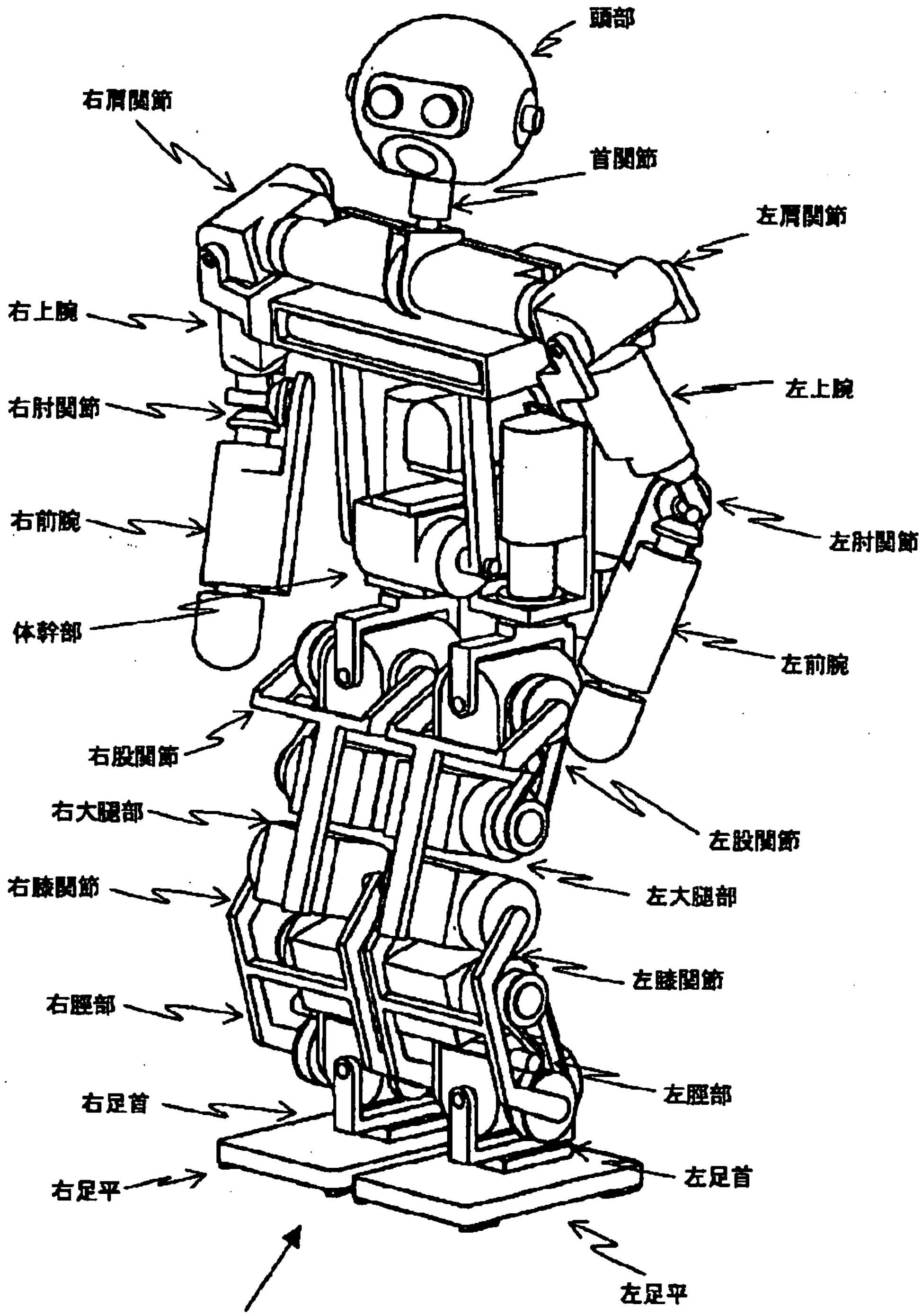
[Drawing 15]



[Drawing 19]

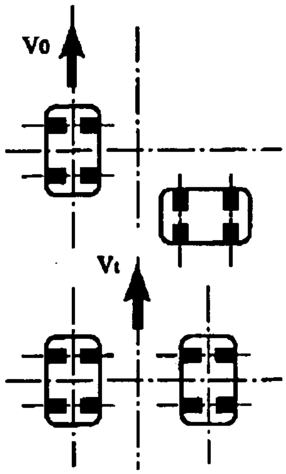


[Drawing 1]

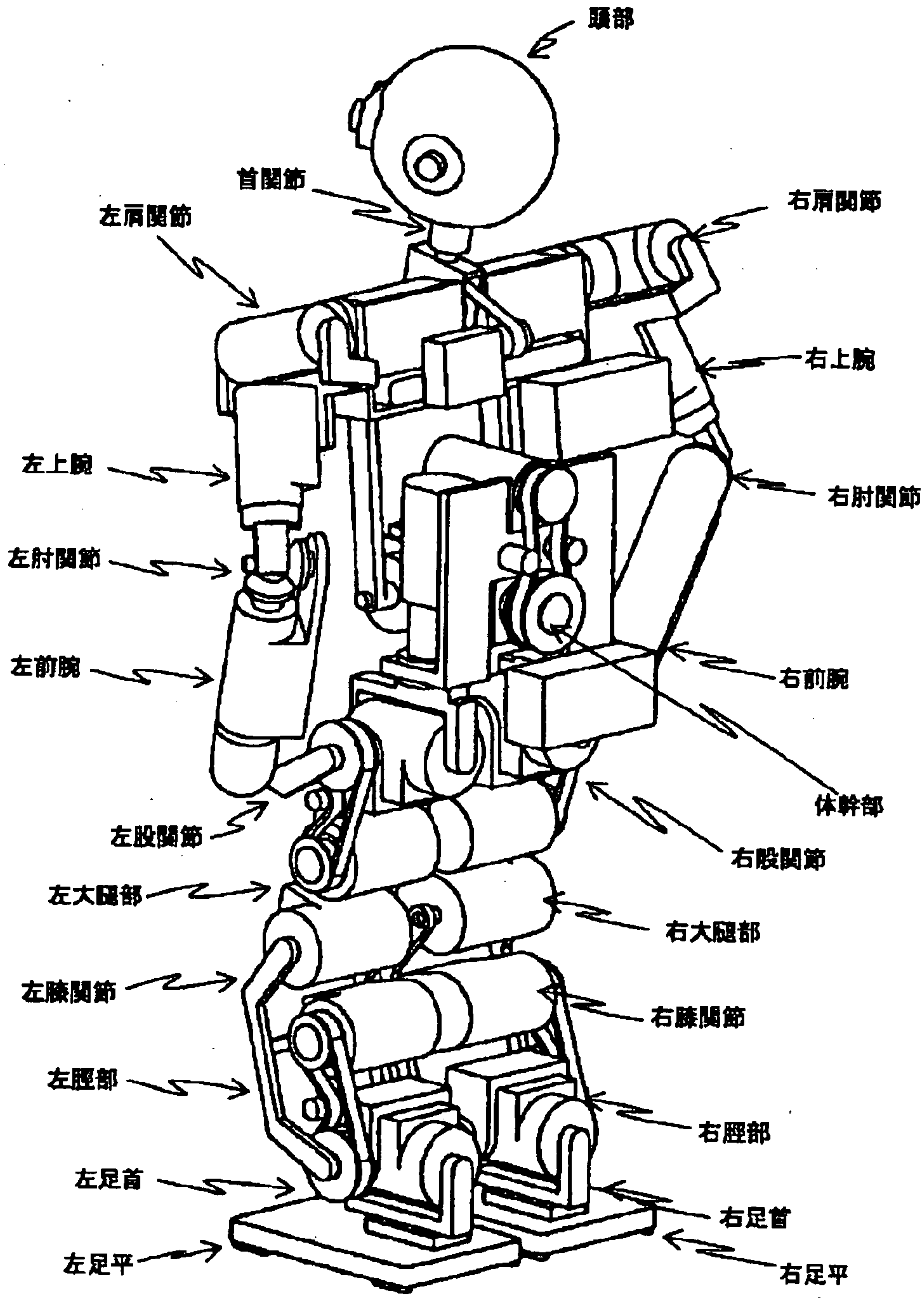


人間型ロボット100
（正面）

[Drawing 17]

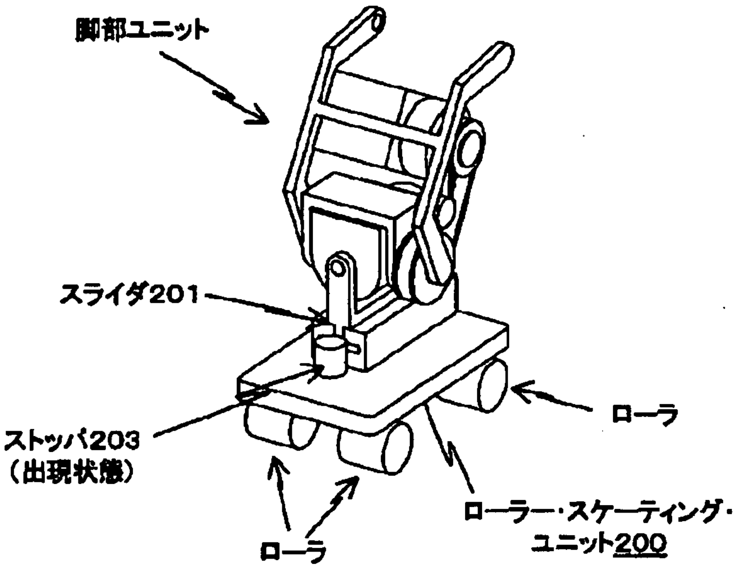


[Drawing 2]

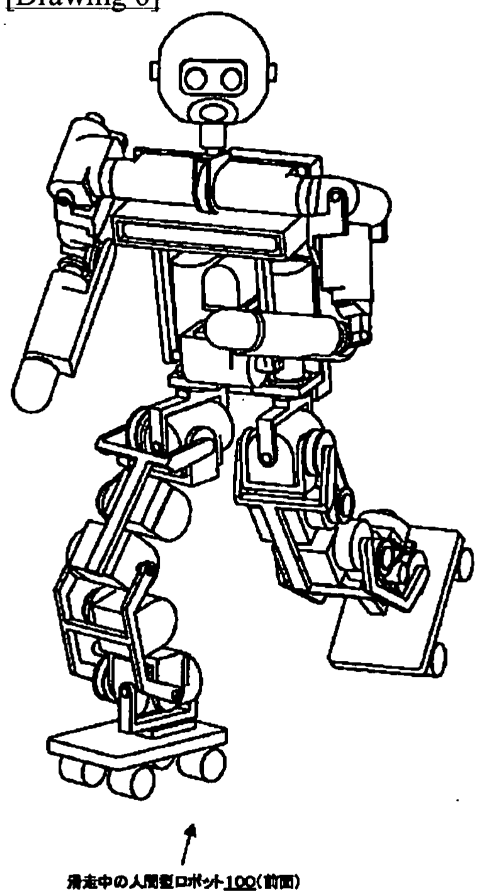


人間型ロボット100
（背面）

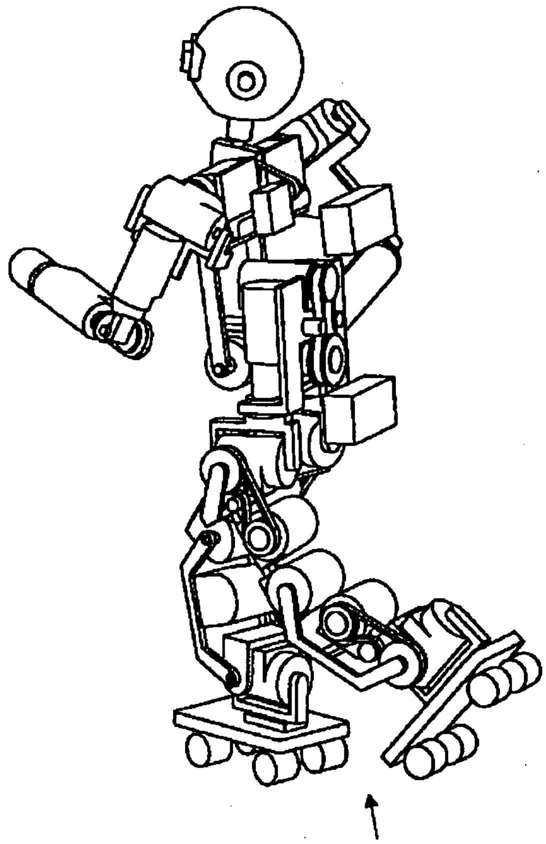
[Drawing 4]



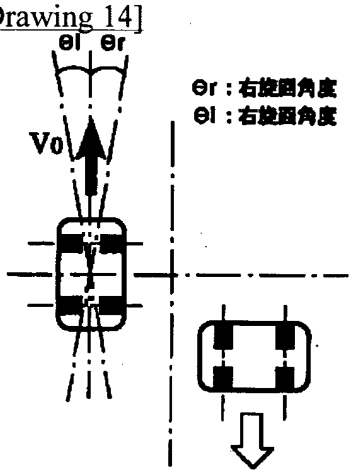
[Drawing 6]



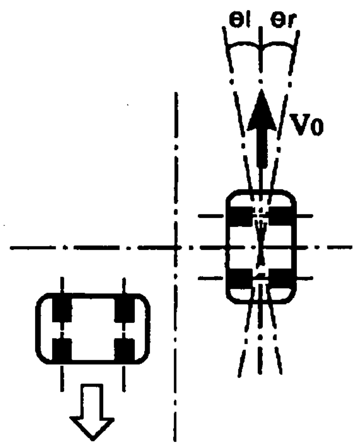
[Drawing 7]



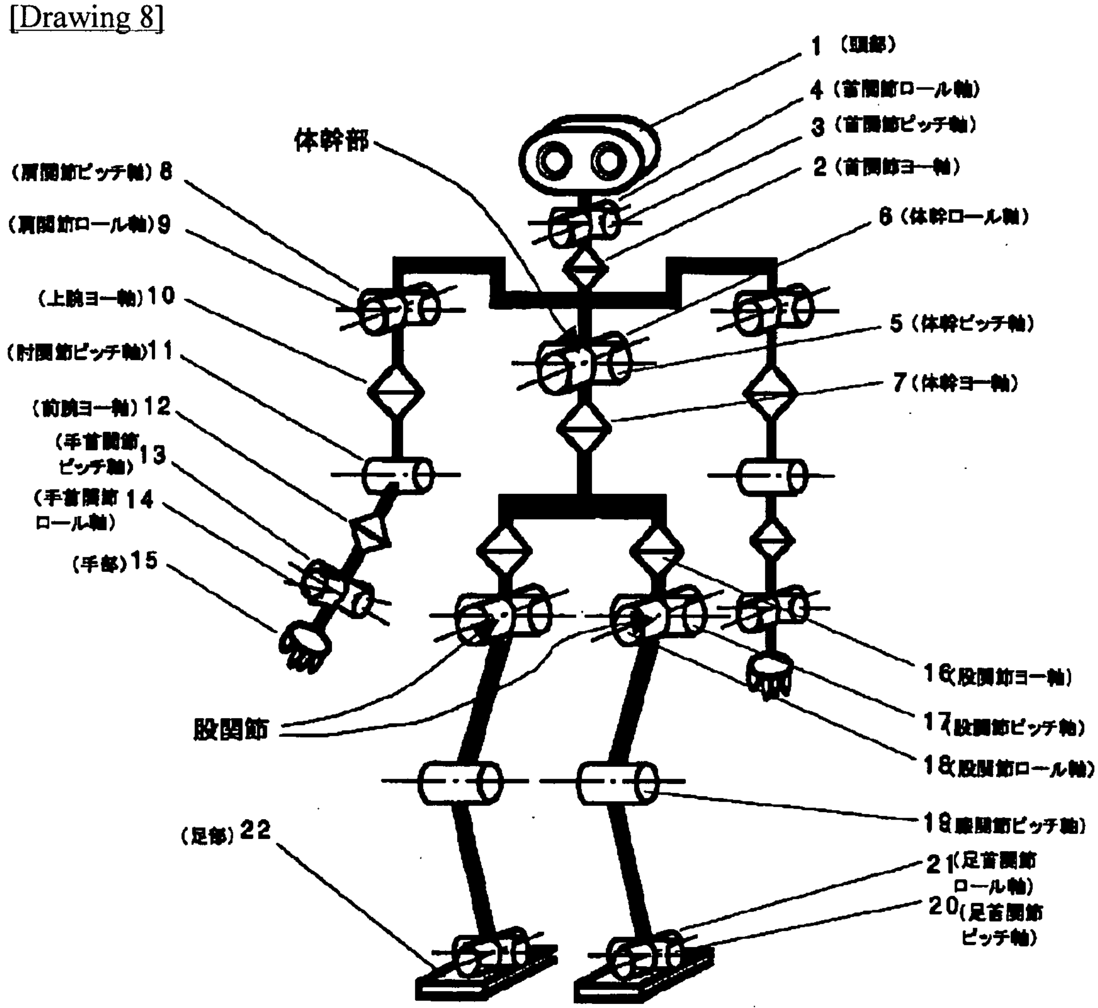
[Drawing 14]



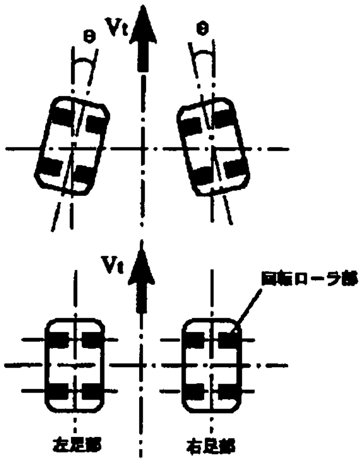
[Drawing 16]



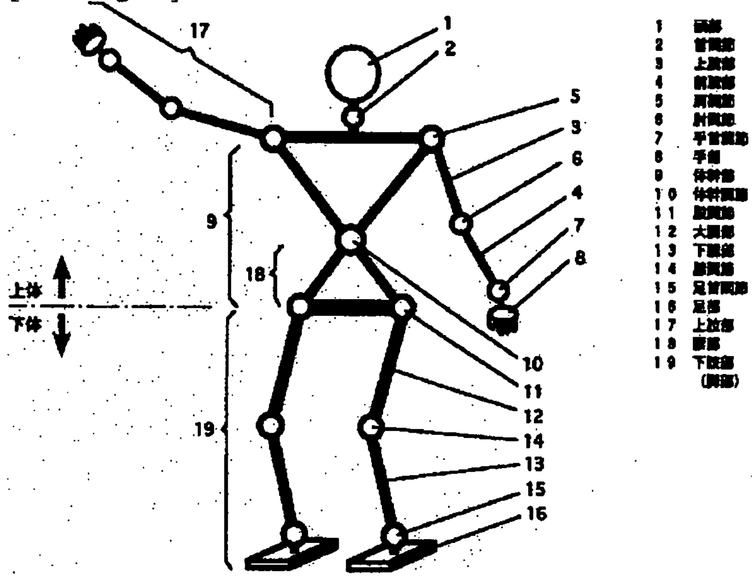
[Drawing 8]



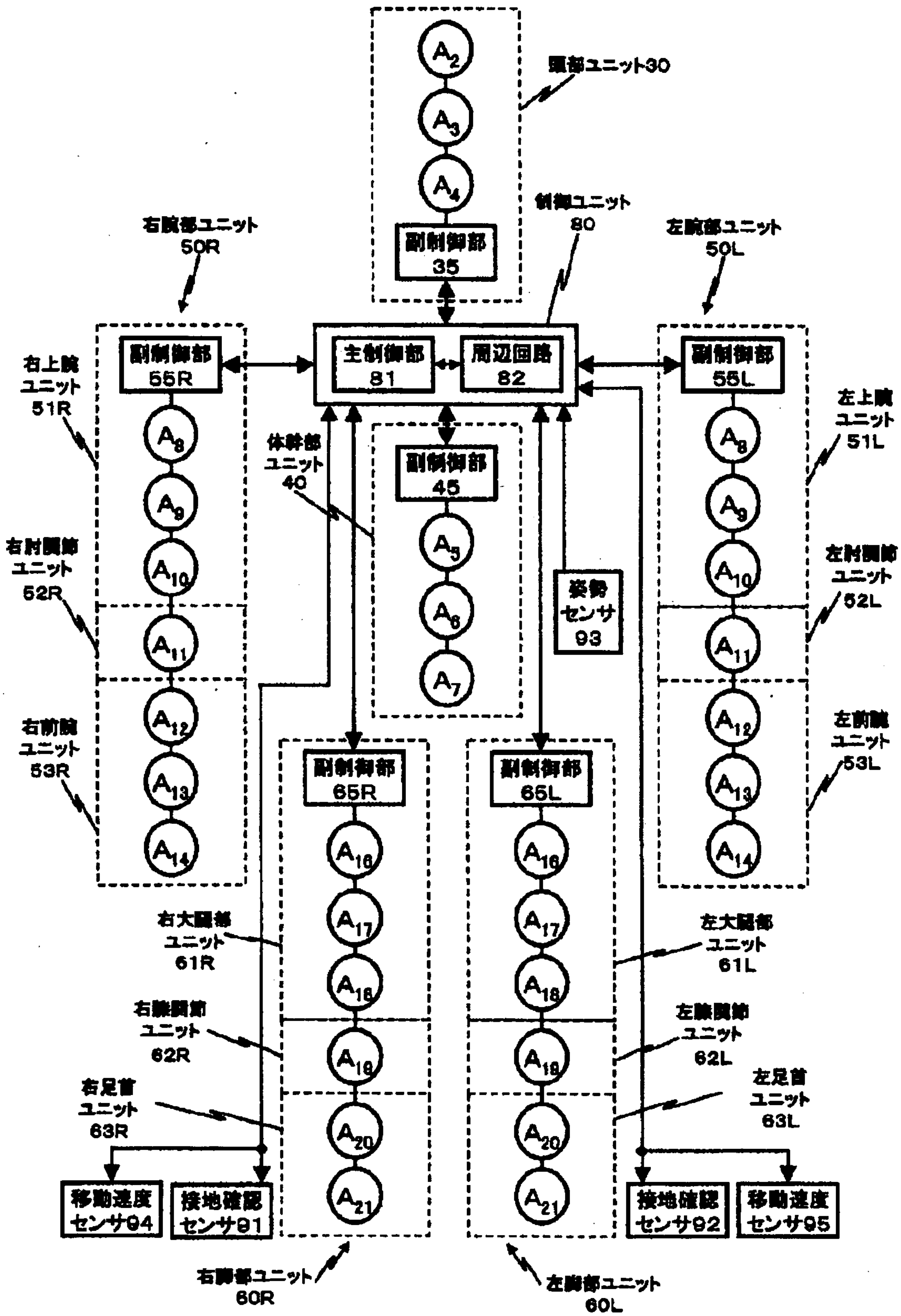
[Drawing 18]



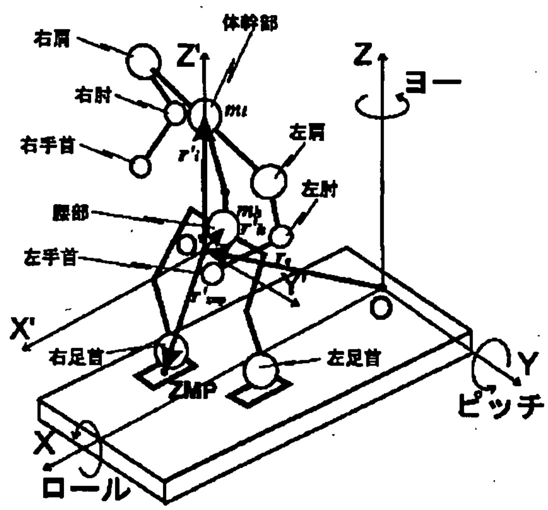
[Drawing 20]



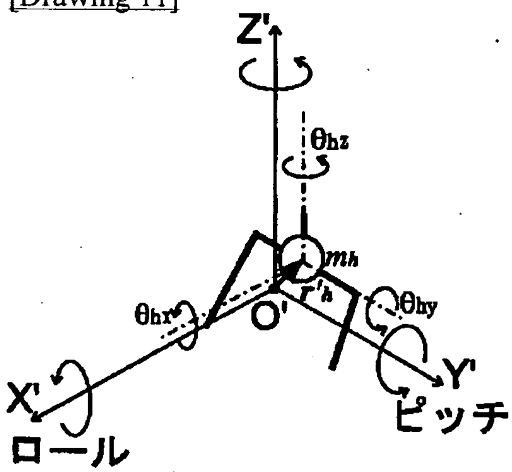
[Drawing 9]


頭部ユニット30
A_2
A_3
A_4
副制御部 35
制御ユニット 80
右腕部ユニット 50R
左腕部ユニット 50L
副制御部 55R
主制御部 81
周辺回路 82
副制御部 55L
右上腕ユニット 51R
左上腕ユニット 51L
体幹部ユニット 40
副制御部 45
A_5
A_6
A_7
姿勢センサ 93
A_8
A_9
A_{10}
A_{11}
A_{12}
A_{13}
A_{14}
右肘関節ユニット 52R
左肘関節ユニット 52L
右前腕ユニット 53R
左前腕ユニット 53L
副制御部 65R
副制御部 65L
A_{16}
A_{17}
A_{18}
A_{19}
A_{20}
A_{21}
右大腿部ユニット 61R
左大腿部ユニット 61L
右膝関節ユニット 62R
左膝関節ユニット 62L
右足首ユニット 63R
左足首ユニット 63L
移動速度センサ94
接地確認センサ91
接地確認センサ92
移動速度センサ95
右脚部ユニット 60R
左脚部ユニット 60L

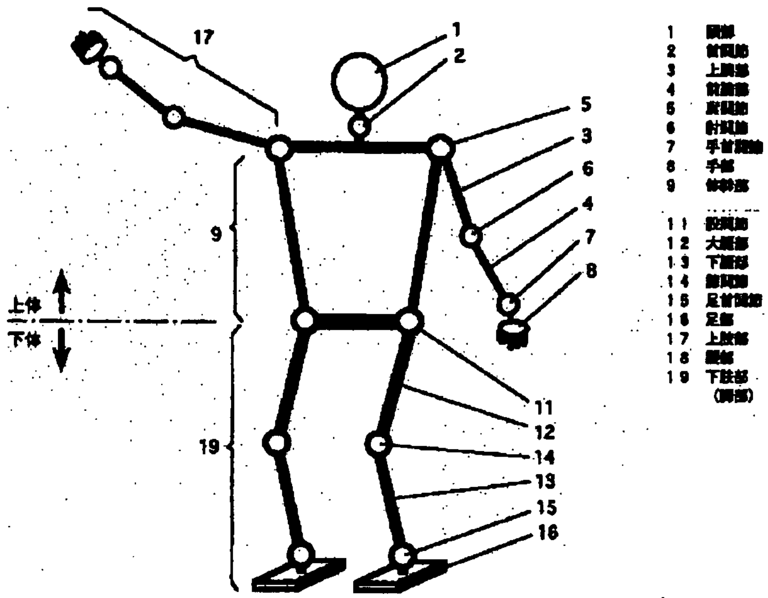
[Drawing 10]



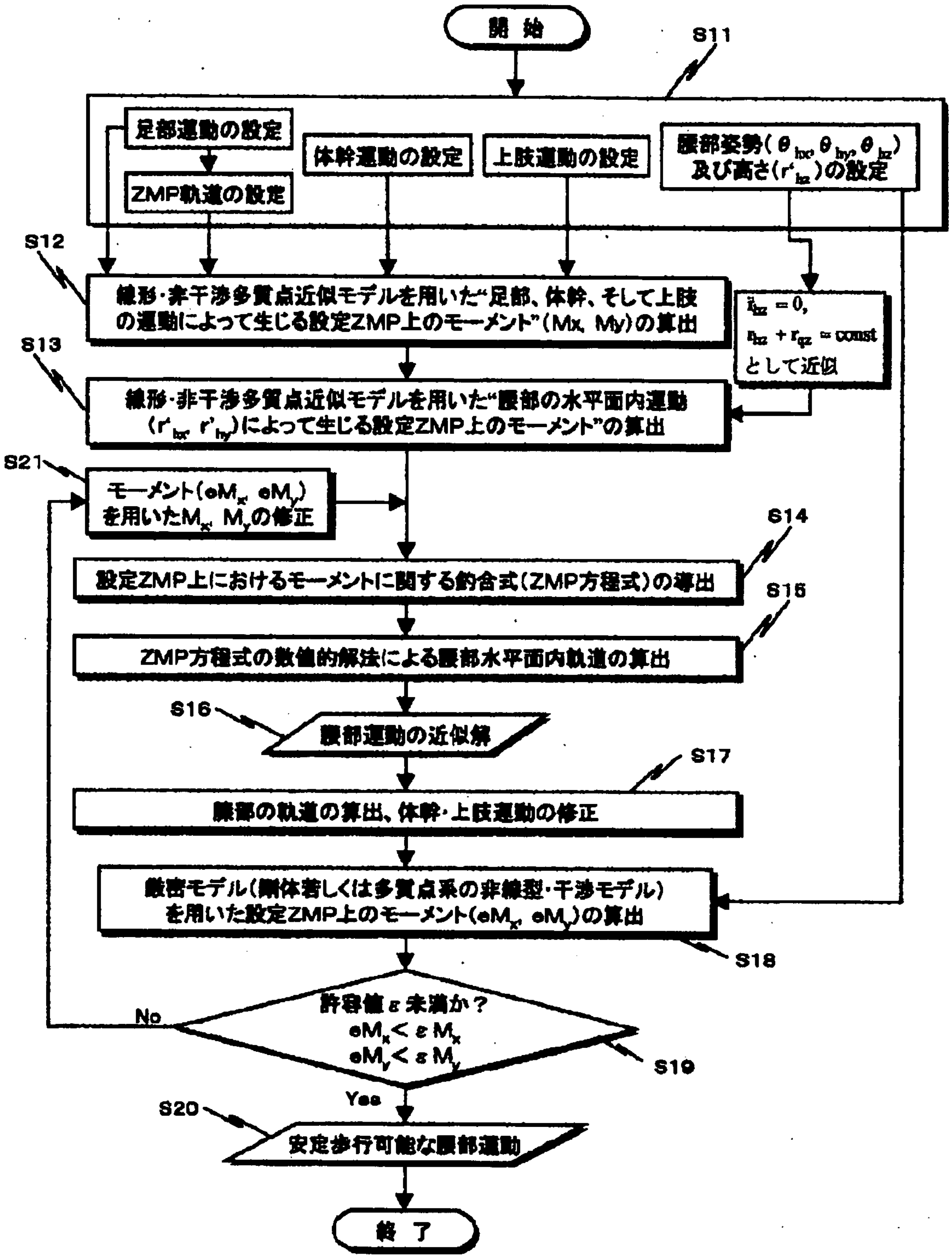
[Drawing 11]



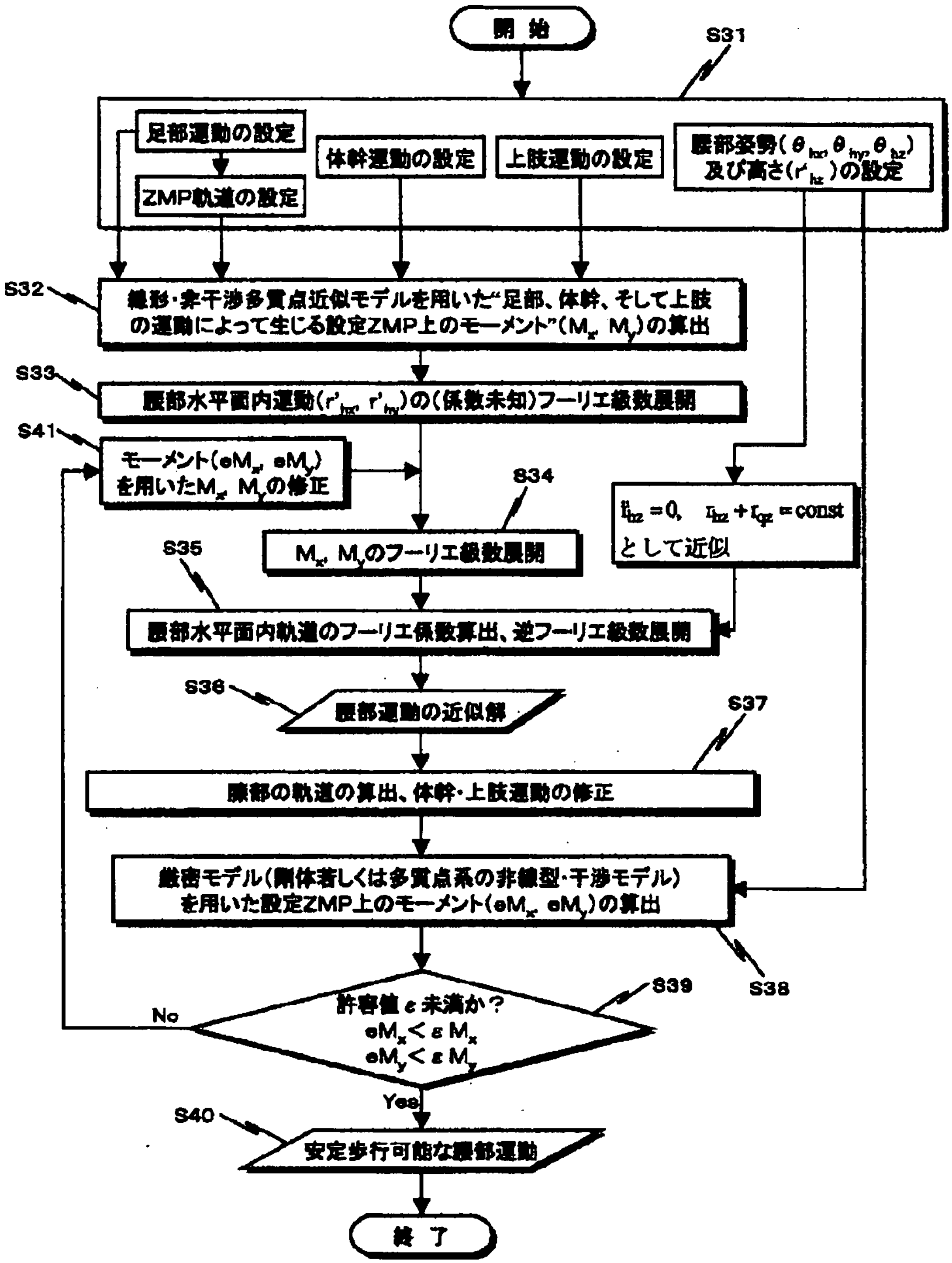
[Drawing 21]



[Drawing 12]


開始
S11
足部運動の設定
ZMP軌道の設定
体幹運動の設定
上肢運動の設定
腰部姿勢(θ_{hx}, θ_{hy}, θ_{hz})及び高さ(r'_{hz})の設定
S12
線形・非干渉多質点近似モデルを用いた"足部、体幹、そして上肢の運動によって生じる設定ZMP上のモーメント"(Mx, My)の算出
$\ddot{r}_{hz}=0$,
$r_{hz}+r_{qz}=\mathrm{const}$
として近似
S13
線形・非干渉多質点近似モデルを用いた"腰部の水平面内運動(r'_{hx}, r'_{hy})によって生じる設定ZMP上のモーメント"の算出
S21
モーメント(eM_x, eM_y)を用いたM_x, M_yの修正
S14
設定ZMP上におけるモーメントに関する釣合式(ZMP方程式)の導出
S15
ZMP方程式の数値的解法による腰部水平面内軌道の算出
S16
腰部運動の近似解
S17
腰部の軌道の算出、体幹・上肢運動の修正
厳密モデル(剛体若しくは多質点系の非線型・干渉モデル)を用いた設定ZMP上のモーメント(eM_x, eM_y)の算出
S18
許容値ε未満か？
$eM_x < \varepsilon M_x$
$eM_y < \varepsilon M_y$
No
S19
Yes
S20
安定歩行可能な腰部運動
終了

[Drawing 13]



[Translation done.]